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FULL PAPER

Variety difference of physicochemical and cooking properties of selected brown rice from Thailand and Malaysia

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Abstract

Rice is a major staple food in Thailand and Malaysia. Although brown rice is a highly healthy substitute, preference is very low due to its texture and cooking quality. However, there are some brown rice varieties such as Sungyod (SY), Chiang (CH), Lepnok (LP) from Thailand and long grain specialty 1(LS_1) and long grain specialty 2 (LS_2) from Malaysian peninsula are commonly consumed in such areas. This study aimed to investigate the physicochemical and the cooking properties of these brown rice to understand the properties for better utilization. Therefore, Rapid visvo analyser (RVA), soaking characteristics, general cooking properties, textural properties and calorific values were measured and compared in 5 varieties of brown rice. Hydration kinetics indicated that LS_1 and LS_2 were faster in water absorption to reach plateau compared to the SY, LP, and CH. The cooking time of these brown rice was in the range from 29 to 35 min. The cooked brown rice had length/breadth (L/B) ratio (2.4 – 3.0), water uptake ratio (2.5 – 3.0), elongation ratio (1.1 –1.4) and gruel solid loss (3.2 – 5.2%). The hardness and the cohesiveness measured from texture analyzer were in the range of 6.75 – 15.5 N and 0.13 – 0.16. There was a significant variation in RVA pasting property of whole rice flour ($p < 0.05$). The variations of different properties of brown rice could be considered for the processing of brown rice and its application.

1. Introduction

Rice has been a staple food of half of the world's population. About 20% of total calorie is assumed to be supplied from rice alone compared to the wheat (19%) and maize (5%) (Shinde *et al*., 2014). Data shows rice consumption is about 82.5% of total production (about 496.9 million tons) globally in 2013/14 (FAO, 2014).

Rice is a popular staple food in East Asian countries including Thailand and Malaysia. Cultivation of different varieties of rice has been in practice in these regions in terms of size, color, taste and cooking properties (Norimah *et al.,* 2008). Rice can be found in different shapes, sizes, colors, aroma with soft to hard cooking quality as well and nutritional properties (Kennedy and Burlingame, 2003). Preference of rice is seen mainly upon texture, appearance, size, aroma and nutritional values (Fitzgerald *et al.,* 2009). The economic value of rice in terms of price is governed mainly by textural properties (Kaur *et al.,* 2014). Compared to common staple white rice, brown rice is considered highly nutritious due to the presence of dietary fibers, vitamins, minerals and bioactive compounds (Dipti *et al.,* 2012), however, preference is less due to its hard texture and poor cooking quality. A number of studies are focused on to prepare brown rice for improved cooking and sensory qualities such as quick-cooking brown rice (Sabularse *et al.*, 1991), enzyme-treated rice (Watanabe *et al.,* 1991), high pressure treated rice (Boluda-Aguilar *et al.*, 2013). However, none of the mentioned techniques was successful to get the desired cooking quality of brown rice. Alternatively, progress has been made to achieve similar health benefits of brown rice by incorporating brown rice flours in flour-based products such as pasta, noodle, porridge, baby and geriatric foods. The physicochemical properties such as the textural properties and the pasting properties are considered important attributes of rice quality that can help to understand appropriate application of brown rice as such or in different product forms. Therefore, this study is aimed to investigate the cooking, textural and pasting properties of five varieties of brown rice sold in the Southern Thailand and the East coast of Malaysia. This study could be useful to understand the properties of the brown rice attributed to higher preference by local

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people and also for better utilization as healthy substitutes of the white rice.

2. Materials and methods

2.1 Samples

Paddies of three varieties namely Chiang (CH), Lepnok (LP) and Sungyod (SY) grown in Phathalung rice research center, Southern Thailand and were selected and dehusked. Commercially available brown rice of two varieties, LS_1, and LS_2 from Malaysia were also used for this study. All the rice samples were well stored below 4°C in plastic bags (vacuum packed). All the samples were brought to normal temperature before carrying out analysis. The moisture content of rice was determined according to AOAC (2000). All of the following measurements were done in ≥ 3 times (triplicate).

2.2 Rapid visco analyser (RVA) pasting properties

Pasting properties of the brown rice flour were determined by using RVA (RVA 4D, Newport Scientific, Australia). Three grams of sample (14% moisture content basis) and calculated amount of distilled water was added into a canister. Rapid visco analyser with Thermocline software was used to analyse pasting properties. The heating profile was set to 50°C for 1 min 30 s, increased temperature up to 95°C within 3 min 45 s. The sample was kept at 95°C for 2 min 30 s and decreased up to 50°C within 3 min 45 s. Pasting properties such as peak viscosity, breakdown viscosity, trough viscosity, final viscosity, setback viscosity, peak time and peak temperature were recorded.

2.3 Soaking characteristics

Brown rice (2 g) was soaked in 25 mL of distilled water at room temperature (34°C) and taken out after 15, 30, 60, 90, 120, 150 and 180 mins. After drying by paper towels, these soaked brown rice samples were weighed to estimate the amount of water uptake.

2.4 General cooking properties of brown rice

2.4.1 Minimum cooking time

Brown rice (2 g) was cooked in a test tube with 25 mL distilled water in boiling water. The minimum cooking time was taken as the time required to lose opaqueness of the endosperm of rice kernels (Singh *et al*., 2005).

2.4.2 Water uptake ratio

The water uptake ratio was determined following the method suggested by Singh *et al*. (2005). Brown rice (2 g) was cooked in 20 mL distilled water for a minimum cooking time in a boiling water bath. After draining the water, the surface of the cooked rice was dried using paper towels. The water uptake ratio was determined by dividing the weight of cooked rice to the weight of raw rice.

2.4.3 Elongation ratio

Elongation ratio (ER) of brown rice was determined by dividing the length of 10 cooked kernels to the 10 uncooked kernels (Singh *et al.,* 2005).

2.4.4 Cooked length–breadth ratio (L/B ratio)

The cooked length-breadth ratio was determined by dividing the length of 10 cooked kernels by the breadth of the same kernels (Singh *et al.,* 2005).

2.4.5 Gruel solid loss

Gruel solid loss was determined with modification of the method given by Juliano (1985). Sample (2 g) was cooked to minimum cooking time in a test tube (20 mL distilled water) with a set temperature (100°C). Using a strainer, the cooked rice and gruel was separated out. The gruel was dried at 105°C until constant weight to find the solid present.

2.5 Textural properties

The texture of cooked brown rice was carried out using a texture analyser (Stable Micro Systems, TA.XT.Plus, Texture Technologies Corp., UK). Texture profile analysis of cooked rice samples was carried out according to the modified method of Mohapatra and Bal (2006). The texture profile was recorded through the computer program. Brown rice of 10 g was cooked to minimum cooking time. About two to three cooked rice kernels used for texture analysis. A two-cycle compression force versus time program was used to compress the samples until 90% of the total strain. A 6-mm diameter probe was used to compress the rice kernels, with pre-test and post-test speeds of 1 mm/sec and test speed of 0.5 mm/sec. Parameters recorded from the test curves were hardness, adhesiveness, and cohesiveness. All textural analyses were replicated at least 6 times per sample.

2.6 Calorific value

Determination of calorific value was carried out by Bomb calorimeter (Berfungsi, IKA C 2000 model, Malaysia) method. The brown rice sample was dried at 100°C, cooled in a desiccator and about 500 mg was taken to make a pellet. The pellet was put inside a bomb calorimeter and that was run to analyse the calorific value in terms of kcal/g dry weight.

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2.7 Statistical analysis

The data were expressed as means ± standard deviation (SD) from all the measured data for each treatment. Data were analysed using SPSS version 20.0 (SPSS, Inc. Chicago) and MS excel 2010. The differences among average values were estimated by analysis of variance (ANOVA) and the level of significance was determined by Tukey's test at p<0.05.

3. Results and discussion

3.1 Soaking characteristics

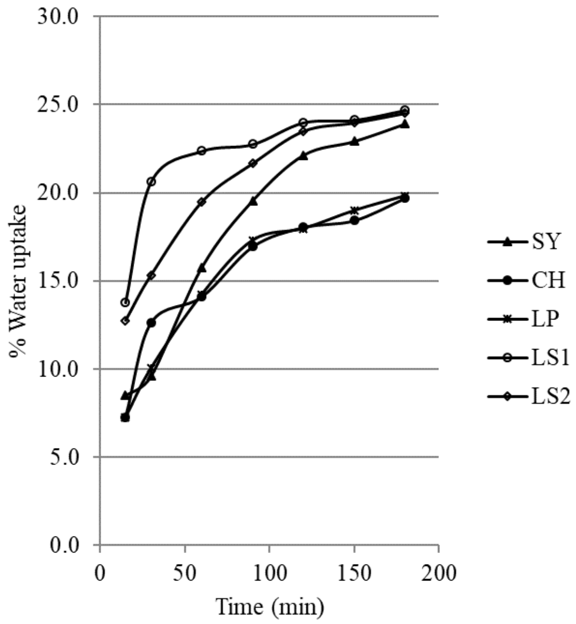

Figure 1. Soaking kinetics of five varieties of brown rice. SY: Sangyod, CH: Chiang, LP: Lepnok, LS_1: Long grain specialty 1, LS_2: Long grain specialty 2.

The soaking characteristics of different brown rice are shown in Figure 1. The hydration curves showed that water absorption increased sharply for 15 – 30 mins of soaking, for all varieties except for SY. Soaking resulted in up to 24% water absorption within 3 hrs. Similarly, absorption of water ranged from 17 to 21% within a period of 2 hrs in all five varieties. Until 2 hrs period, there was a faster rate of soaking, thereafter; comparatively slower rate (plateau) was observed (Figure 1). From the soaking kinetics, the minimum soaking period of brown rice was determined to be 2 hrs. Many studies on white rice have reported an optimum soaking period of 30 mins to 60 mins as plateau moisture level (Chiang and Yeh, 2002; Boluda-Aguilar *et al*., 2013). Soaking (at least 30 mins) before cooking results in better cooking quality (Chakkaravarthi *et al*., 2008). The intact bran in brown rice affects the soaking kinetics in brown rice (Han and Lim, 2009) however, soaking kinetics in polished rice entirely depends on time, temperature and solute level. A study on the hydration kinetics of milled rice showed that there was a higher rate of water absorption during the first 30 mins (Das *et al.,* 2006). In the present study, SY (red-pigmented brown rice) was found to have slower water penetration rate compared to other varieties for the first 30 mins however, the rate of absorption increased afterwards. Water penetration was rapid (up to 13%) for the first 15 min in case of LS_1 and LS_2 unlike SY, CH, and LP (Figure 1). Pre-soaking has been found to reduce the cooking time by more than 10 mins in a study conducted using the rice cooker (Das *et al.,* 2006).

3.2 General cooking properties

General cooking properties included minimum cooking time (MCT), cooked L/B ratio, elongation ratio (ER), gruel solid loss and water uptake (WU) ratio (Table 1). The MCT of five varieties ranged from 29 to 35 mins with the highest for CH (35 mins) and the lowest (29 mins) for LS_1. The variation in cooking time may be the difference in thickness and characteristic of the outer intact bran layer that influences the penetration of water (Wu *et al.,* 2014). A study on the cooking of rice reported that the cuticle layer in brown rice was the primary structure leading to low water absorption, elongation of cooking time and reduction in volume expansion (Wu *et al*., 2014).

L/B ratio of cooked five varieties ranged from 2.4 to 3.0. In the present study, the LS_2 variety showed the highest ratio of cooked L/B. Only LP and LS_2 had found significantly different (p<0.05) in terms of L/B ratio. All five varieties of brown rice gave WU ratio in the range of 2.5 to 3.0, where the highest WU ratio was given by LS_1 variety. A significant difference (p<0.05) was found in the WU ratio of SY, LP, LS_1, and LS_2. Similarly, the ER value of all the five varieties was found in the range of 1.1 to 1.4. There is a significant difference (p<0.05) in the mean values of ER of SY and LS_2.

Gruel solid loss of the five varieties was in the range of 3.2 (Lepnok) to 5.2% (LS_1). LP showed the least leaching compared to the highest by LS1. Gruel solid loss indicates that during cooking, rice kernels gelatinize and amylose of the granules may come out of the kernels.

Cooking properties is considered to play a significant role as rice quality attribute. Cooking implies the gelatinization of starch and rate of gelatinization of brown rice is less compared to polished rice (Billiris *et al*., 2012). White rice having low gelatinization rate takes less than 20 mins cooking (Singh *et al.,* 2005), however, this is not the case for brown rice in which cooking time is depended on rice (Das *et al*., 2008). A previous study has reported rice having higher L/B ratio

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Table 1. Cooking properties of five varieties of brown rice

Variety	MCT (min)	L/B ratio	WU ratio	ER	Gruel solid loss (%)
SY	34±0.0^{d}	2.7±0.4^{ab}	2.5±0.1^{a}	1.1±0.1^{a}	4.4±0.2^{bc}
CH	35±0.0^{e}	2.9±0.6^{ab}	2.5±0.1^{ab}	1.3±0.1^{ab}	4.0±0.5^{ab}
LP	31±0.0^{b}	2.4±0.3^{a}	2.6±0.0^{b}	1.3±0.1^{ab}	3.2±0.3^{a}
LS_1	29±0.0^{a}	2.9±0.3^{ab}	3.0±0.0^{d}	1.3±0.1^{ab}	5.2±0.7^{c}
LS_2	33±0.0^{c}	3.0±0.4^{b}	2.8±0.1^{c}	1.4±0.1^{b}	3.4±0.1^{ab}

Values are mean±SD. Different superscript small case letters in the same column represent significance difference (p<0.05). MCT: minimum cooking time, L/B: length /breadth, WU: water uptake, ER: Elongation ratio, SY: Sangyod, CH: Chiang, LP: Lepnok, LS1: Long grain specialty 1, LS2: Long grain specialty 2.

gives a higher elongation ratio as well as higher WU ratio (Singh *et al.*, 2005). It is because of the higher surface of rice kernels that help faster absorption of water in the cooking medium. Gruel solid loss is considered a factor depending upon the aging of rice (Sodhi *et al.*, 2003). However, in the present study, gruel resulted in due to longer cooking period, and also due to leaching through disintegrated bran in the ventral surface. The gruel solid loss corresponded to the L/B ratio as seen in LS_1 and Lepnok indicated that gruel increased with respect to increasing the surface area of kernels.

3.3 Textural properties

The textural properties of brown rice are presented in Table 2. Hardness, cohesiveness, and adhesiveness of cooked brown rice ranged from 6.75 to 15.5 N, 0.13 to 0.16 and –0.05 to –0.25 N.Sec respectively. Red-Pigmented and low amylose (12.8%) Sungyod variety showed the highest value of hardness, however, it is known that Sungyod is considerably soft in its milled form. It indicates that brown rice form of Sungyod may be hard due to its higher content of the bran layer. Malaysian LS_1 had the lowest of hardness (6.75 N) among five varieties. Long grain varieties of intermediate amylose content are normally found popular due to soft texture and LS_1 has retained that property. The considerably low hardness of LS_1 is assumed due to the likely presence of thin bran layer. Similarly, there was no significant difference in cohesiveness among studied varieties. A very low and no significant difference (p>0.05) was observed in adhesiveness indicated brown rice has less adhesiveness. It might be due to slippery bran of rice. Milled rice is reported to be high in adhesiveness. A study on rice reported amylose influenced on hardness, cohesiveness, and adhesiveness. A recent study also reported that the aleurone layer and cuticle layer significantly enhanced the hardness and decreased the adhesiveness of cooked rice (Wu *et al.,* 2014).

Table 2. Textural properties of five varieties of cooked brown rice varieties

Brown rice	Hardness (N)	Cohesiveness	Adhesiveness (N.Sec)
CH	11.16±4.49^{ab}	0.15±0.03^{a}	-0.05±0.07^{a}
SY	15.50±5.16^{b}	0.16±0.02^{a}	-0.25±0.27^{a}
LP	8.18±3.02^{a}	0.13±0.05^{a}	-0.17±0.16^{a}
LS_1	6.75±5.75^{a}	0.16±0.05^{a}	-0.18±0.05^{a}
LS_2	9.91±5.07^{ab}	0.15±0.04^{a}	-0.24±0.05^{a}

Values are mean± SD. Different superscript small case letters in the same column indicate significant difference (p<0.05). SY: Sangyod, CH: Chiang, LP: Lepnok, LS1: Long grain specialty 1, LS2: Long grain specialty 2.

3.4 Pasting properties

The pasting properties of five brown rice varieties analysed by RVA are presented in Table 3. A significantly low pasting temperature of LP (84.8°C) indicated a low gelatinization temperature of LP compared to the rest varieties. The low and high pasting temperature was used to adjust the cooking time (Bap, 2008). Peak viscosity ranged from 1254 (SY) to 1569 cP (LS_2). Peak viscosity is the indication of the degree of the swelling capacity of starch during cooking (Choi *et al.,* 2012).

The breakdown viscosity (BD) was in the range of 48 to 440 cP. The highest value of BD was seen in the case of Lepnok and the lowest for CH. The low value of breakdown viscosity indicated that CH could make

Table 3. Pasting properties of five varieties of brown rice by RVA

Variety	Viscosity (cP)					Peak time (min)	Pasting Temp (^{0}C)
	Peak	Trough	Breakdown	Final	Setback		
CH	1490±28^{bc}	1443±3^{c}	48±18^{a}	4157.0±31^{d}	2714±7^{d}	5.82±0.5	88.0±0.0^{c}
SY	1254±13^{a}	1144±1^{b}	110±2^{b}	2563.7±21^{a}	1419±12^{a}	5.29±0.1	86.4±0.0^{b}
LP	1452±25^{b}	1012±7^{a}	440±33^{d}	2754.0±46^{b}	1742±39^{b}	5.57±0.5	84.8±0.3^{a}
LS_1	1550±34^{cd}	1161±3^{b}	389±10^{cd}	3697.0±64^{c}	2536±30^{c}	5.49±0.0	88.1±0.1^{c}
LS_2	1569±23^{d}	1187±4^{b}	382±19^{c}	3755.0±81^{c}	2568±52^{c}	5.46±0.1	88.0±0.1^{c}

SY: Sangyod, CH: Chiang, LP: Lepnok, LS1: Long grain specialty 1, LS2: Long grain specialty 2.

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comparatively more stable hot paste than rest brown rice flours. Setback viscosity was in the range of 1419 to 2714 cP. Significantly lower setback value of SY and the highest of CH was seen, and this property reflects the lower and higher retrogradation properties respectively. Setback viscosity is a result of rearrangement of gelatinized starch granules (retrogradation) resulting in final viscosity (Choi *et al*., 2012). The final viscosity was found in the range 2564 to 4157 cP. The highest and the lowest final viscosity was found for CH and SY respectively. In the cooked form, the pasting behaviour of the rice flour is reflected by final viscosity. Due to the high final viscosity as seen by RVA, CH would give viscous paste in comparison to other rice varieties. The peak time of the CH, SY, LP, LS_1 and LS_2 samples was in decreasing order. The highest peak time of CH indicated that gelatinization occurred slowly to reach peak viscosity. The amount of bran layer present on kernel could be the decisive factor for such a prolonged peak time. It was observed that pasting temperature was higher for the brown rice flour which had high peak time. Characteristics of raw rice flour are elucidated which clearly showed uniformity of patterns such as peak-time from 5 – 6 mins.

3.5 Calorific value

The calorie content of different brown rice varieties is presented in Table 4. Gross energy measured by bomb calorimeter ranged from 413.3 – 432.2 kcal/100 g. The lowest calorific value was found in LP and the highest in SY. The total calorie content of SY was not significantly different from CH (426.2 kcal/100 g) at p>0.05; however, LP, LS_1, and LS_2 were significantly different (p<0.05). On comparison of energy by using the Atwater factor and bomb method, a difference of maximum (26%) was found in the case of CH.

Table 4. Calorific values of raw brown rice by bomb method and compare with Atwater factor calculation

Variety	Calorific values (Kcal/100 g)		
	Net energy (Atwater factor)	Gross energy (Bomb method)	% difference
SY	325.5	432.2 ± 4.3^{c}	24.7
CH	313.6	426.2 ± 21.6^{bc}	26.4
LP	334.2	413.3 ± 16.6^{a}	19.1
LS_1	340.2	424.4 ± 45.0^{b}	19.8
LS_2	333.7	423.1 ± 8.4^{b}	21.1

Values are mean ± SD. Different superscripts within the same row are significantly different (p< 0.05). SY: Sangyod, CH: Chiang, LP: Lepnok, LS1: Long grain specialty 1, LS2: Long grain specialty 2.

4. Conclusion

Physicochemical and cooking properties of five brown rice varieties were investigated. Hydration kinetics showed soaking can be used to reduce the cooking time. Different cooking times among varieties have an influence on the cooking properties such as cooked L/B ratio, water uptake ratio, elongation ratio, and gruel solid loss. The energy value of brown rice varieties determined from bomb calorimeter was higher than energy calculated based on Atwater factor. The textural hardness of different varieties varied significantly. Pasting properties revealed some varieties could give stable hot paste or soft gel or hard gel due to its varying physicochemical properties. On the basis of physicochemical and cooking properties, brown rice of different varieties could be used for different purposes, for example, cooking as such in cooked kernel form or flours.

Conflict of Interest

The authors declare no conflict of interest.

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